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Evaluation of disinfectants in the domestic environment under 'in use' conditions

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SUMMARY

An 'in use' test was developed to investigate effectiveness of disinfectant application and of detergent of hot water cleaning at kitchen, bathroom and toilet sites in the domestic environment. Detergent and hot water cleaning produced no observable reduction in microbial contamination. Single and daily application tests demonstrated that hypochlorite and phenolic disinfectants can be used to produce substantial reductions in bacterial contamination in the home. Results indicate that maximum protection afforded by disinfection is relatively brief; 3–6 h after disinfection, contamination levels were only marginally less than those observed at pretreatment. Some suggestions are made for improvements in home hygiene.

INTRODUCTION

Market survey data indicates the wide range of disinfectants and disinfectant/cleaning products which are used in the home (*Which Report*, 1972, 1976). The activity of these products may be established by laboratory tests such as the Rideal Walker or standard use-dilution tests (British Standard 5197 specifies an RW coefficient of not less than 3·0 for aromatic disinfectant fluids). In addition, for disinfectants used in hospitals, tests have been carried out on environmental surfaces which are artificially contaminated or under normal conditions of use (Ayliffe, Collins & Lowbury, 1966; Litsky & Litsky, 1968; Ojajarvi & Makela, 1974; Duppre, 1975).

In this investigation a method was developed for 'in use' testing of disinfection

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procedures and was used to compare the relative effectiveness of chemical disinfection and detergent and hot water cleaning in the domestic environment.

An earlier study of microbial contamination in the home (Scott, Bloomfield & Barlow, 1982) indicated sites which are most likely to represent a potential infection hazard. These include the kitchen sink surface, U-tube and draining board, nappy bucket and toilet, which may act as permanent reservoirs of large numbers of bacteria, whilst items such as dishcloths and cleaning cloths may form not only reservoirs but also act as disseminators of bacteria in the home. Contamination of hand-contact sites and food preparation sites were also sufficient to justify concern. Investigations of disinfection and cleaning procedures as described here were concentrated at these sites.

MATERIALS AND METHODS

Home and sample sites

Householders were recruited from those who participated in the original survey (Scott, Bloomfield & Barlow, 1981, 1982). Test sites in the kitchen included the worktop, chopping board, draining board, sink surface, sink U-tube, dishcloth and cleaning cloth. Test sites in the bathroom and toilet were the basin surface, toilet seat and toilet water.

Media

Except where otherwise specified, culture media were prepared and supplied by Tissue Culture Services Ltd (Slough, Bucks) using media bases obtained from Oxoid Ltd.

Sampling methods

Sampling methods are as described by Scott *et al.* (1981) with some modifications. Surfaces were sampled by placing blood agar Rodac plates in contact for 10 s. Serum-coated swabs pre-moistened with one-quarter strength Ringer solution were also used to sample areas of approximately 50 cm^2 adjacent to the contact sample area, and returned immediately to plastic containers.

Liquid samples (10 ml) from toilets and U-tubes where soap and water cleaning was applied were transferred to contact slide containers. Liquid samples (1 ml) from sites treated with either phenolic or hypochlorite disinfectants were pipetted into a universal bottle containing 9 ml of recovery medium. For phenolic disinfectants a solution containing 3 % Tween 80, 0·3 % lecithin, 0·1 % L-histidine was used. For inactivation of hypochlorite, 0·5 % sodium thiosulphate was also added. After shaking, a contact slide was dipped into the solution for 5 s and then returned to its container for incubation.

Samples were returned to the laboratory in an insulated cool-box within 2 h of collection. Swabs and a loopful of each liquid sample were streaked on to MacConkey agar and incubated aerobically together with contact plates and slides at 37 °C for 24 h.

Identification and enumeration of bacteria

Colonial morphology and Gram-staining reactions of all isolates from MacConkey and contact plates were noted. Gram-negative rods were identified by the API 20 system for Enterobacteriacae and other Gram-negative rods (API Laboratory Products Ltd, Farnborough, Hants).

Contamination levels were determined from colony counts on contact plates and contact slides only. For tests with disinfectants, slide counts from liquid samples were multiplied by a factor of 10. Colony counts were grouped into contamination levels which were coded as follows: zero-10 colonies (0), 11–60 colonies (1), 61–120 colonies (2), 121–180 colonies (3), 181–240 colonies (4), greater than 240 colonies (5) per area of contact plate. A colony count of > 240 was assumed for plates showing confluent growth. Differences in contamination levels before and after treatment with disinfectants or detergent and hot water were tested for significance using the Wilcoxon matched-pairs signed-ranks test (Siegel, 1956).

Preparation and standardization of disinfectant and detergent products

Test products comprised a proprietary anionic liquid detergent and two widely used domestic disinfectants: a phenolic disinfectant with an average RW coefficient of 4·6 and a hypochlorite disinfectant with added detergent containing between 9·1 and 9·4% (w/v) available chlorine. Disinfectants were purchased in their original containers and MIC values determined, as described by Scott (1981), to ensure no major variation between containers. For disinfection of sites other than sinks, U-tubes and toilet water, products were diluted according to manufacturers' recommendations: liquid detergent, and phenolic and hypochlorite disinfectants were diluted 1·2, 2·0 and 0·6% (v/v) respectively using tap water at 45 °C.

Laboratory tests to check satisfactory neutralization of disinfectants when recovering organisms from disinfected surfaces are described by Scott (1981).

Test to investigate the effectiveness of a single application of disinfectant or detergent

During the week prior to testing, two viscose-fibre cloths were given to housewives to use as a dishcloth and cleaning cloth in the kitchen and mild liquid detergent was used for 2 days before the test in place of other cleaning and disinfectant products. On the day of the test, sites were sampled between 9 a.m. and 11 a.m. Using a calibrated plastic bowl, housewives prepared three 1-litre quantities of test product which was applied to all surfaces using a new viscose cloth. Using the first bowl of disinfectant, hard surfaces in the kitchen were disinfected in the order given previously. The second bowl of product was used to immerse dischloths and cleaning cloths, which were then wrung out and put aside, and the remaining product used to clean an area of kitchen floor. The third bowl of product was used to clean bathroom and toilet sites. Finally, undiluted disinfectant or detergent was added to the kitchen sink U-tube (3–6 ml) and to the toilet water (12–20 ml). Any excess product was poured down an outside drain. Sites were sampled 15, 90 and 180 min after application of test products.

Housewives were observed to check that procedures were carried out correctly and were instructed not to use test sites between product application and the 180 min sampling time.

Test to investigate the effectiveness of daily application of disinfectants

The effect of daily application of hypochlorite disinfectant was investigated over 3 days. Only kitchen sites were used in this test. Two viscose-fibre cloths were supplied to housewives 1 day prior to testing to use in place of their own dishcloth and kitchen cleaning cloths, but otherwise they were asked to maintain normal cleaning/disinfecting routines. On each day of the test, sites were sampled before disinfection between 9 a.m. and 11 a.m. Housewives then prepared a 1 litre bowl of test product, which was used to clean four kitchen surfaces in the order indicated, using the cleaning cloth that had been in use since the previous day. Dishcloths and cleaning cloths were then 'rinsed out' in the product and excess product poured down the kitchen sink.

On each of the 3 days sites were resampled within 1 h of application of test products and 6 h later. Housewives were instructed not to use any disinfectant or cleaning product other than washing-up liquid but otherwise to continue their normal daily routine.

RESULTS

Single-application test

The effect of detergent and hot water cleaning and disinfectant application was investigated at kitchen, bathroom and toilet sites in 10 houses. Using combined data for all sites in all houses, contamination levels before and after treatment were tested for significance using the Wilcoxon Rank test. Tests with detergent in hot water indicated no significant difference in contamination before and up to 90 min after cleaning, although some reduction ($P = 0{\cdot}025$), probably due to the disinfectant action of drying, was observed at 3 h. By contrast hypochlorite and phenolic disinfectants produced an overall reduction in contamination over the full 3 h period (P values $< 0{\cdot}00006$, $0{\cdot}002$, $0{\cdot}006$ and $< 0{\cdot}00006$, $0{\cdot}001$ and $0{\cdot}0002$ for hypochlorite and phenolic at 15, 90 and 180 min respectively).

To compare relative effectiveness at various sampling times and at different types of sites, the frequency occurrence of heavily contaminated (more than 120 colonies per 25 cm^2) and decontaminated sites (less than 10 colonies per 25 cm^2) was determined as shown in Table 1 and Fig. 1. Table 1 indicates that, in all three tests, the incidence of heavy contamination before treatment was between 56 and 63 %, with only 16–21 % of sites showing counts of 10 or less. After treatment with detergent and hot water, some increase in the incidence of heavy contamination and a corresponding reduction in low contamination levels was observed, although the Wilcoxon Rank test indicated that the differences were not significant. By contrast, after application of hypochlorite only 7 % of sites remained heavily contaminated and, at 73 % of sites, counts of 0–10 colonies were observed. Although the phenolic disinfectant was less effective, occurrence of high contamination levels was reduced from 59 to 36 %, whilst the number of disinfected sites increased to 31 %.

Table 1. *The effect of a single application of disinfectant or of detergent and water cleaning on bacterial contamination of environmental sites in the domestic kitchen, bathroom and toilet*

	Frequency of occurrence of colony counts (%)			
	Before treatment	Time after treatment (min)		
		15	90	180
Detergent and hot water				
Counts greater than 120 per 25 cm²	63·0	68·0	58·9	45·5
Counts less than 10 per 25 cm²	17·4	7·6	15·5	15·5
Total number of sites sampled		92		
Hypochlorite				
Counts greater than 120 per 25 cm²	62·5	55·0	31·1	37·0
Counts less than 10 per 25 cm²	21·0	74·4	32·0	28·0
Total number of sites sampled		90		
Phenolic				
Counts greater than 120 per 25 cm²	56·5	34·0	36·6	34·0
Counts less than 10 per 25 cm²	16·3	37·3	27·7	32·9
Total number of sites sampled		92		

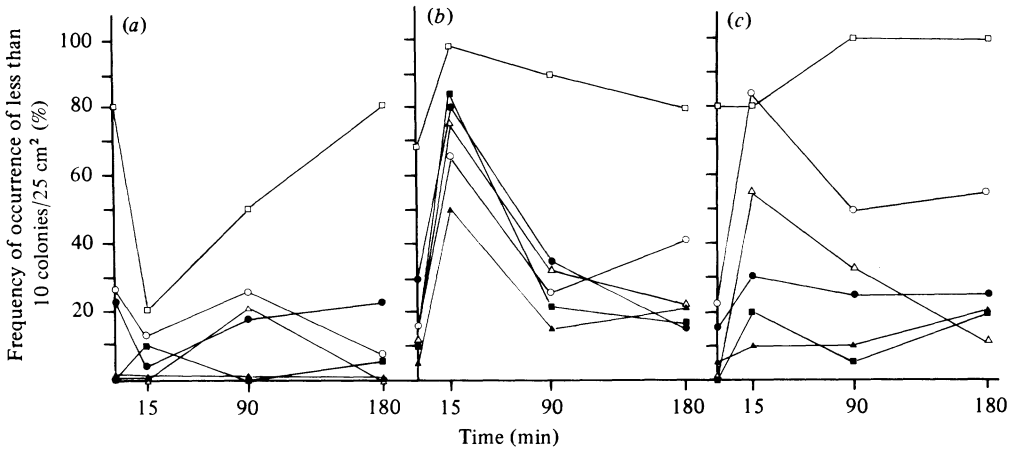

Fig. 1. Frequency of occurrence of contamination levels of less than 10 colonies/25 cm² at environmental sites in the domestic kitchen, bathroom and toilet following (*a*) detergent and hot water cleaning, (*b*) application of hypochlorite disinfectant, (*c*) application of phenolic disinfectant. ●, Worktop and chopping board; ■, draining-board and sink surface; ▲, bath surface and toilet seat; ○, dishcloth and cleaning cloth; △, U-tube; □, toilet water.

For both hypochlorite and phenolic disinfectants, results in both Table 1 and Fig. 1 indicate that, whereas rapid effective decontamination may be achieved within 15 min, in general the effects were relatively short-lived. Within 3 h high contamination levels were re-established at a high proportion of sites.

Results given in Fig. 1 indicate that the pattern of rapid disinfection followed by recontamination over 90–180 min was consistent for all types of sites and there

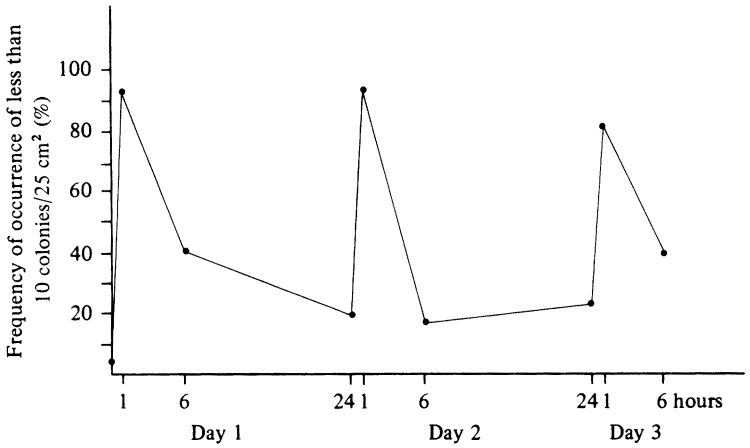

Fig. 2. Frequency of occurrence of contamination levels of less than 10 colonies/25 cm² at environmental sites in the domestic kitchen following daily application of hypochlorite disinfectant over a period of 3 days.

was no particular relationship between the efficiency of the disinfection process and the nature of the site; whereas the phenolic disinfectant was most effective at wet sites such as the U-tube and cloths, producing satisfactory disinfection on 55 % and 85 % of occasions, disinfection with hypochlorite was consistently achieved not only at kitchen drainer, sink surfaces and U-tubes but also at relatively dry sites such as the worktop and chopping board (75–85 %). By contrast, the performance of the phenolic disinfectant on worktops and chopping boards was relatively poor – only 25–30 % of these sites were disinfected satisfactorily. The low level of contamination associated with the domestic toilet both before as well as after disinfection (70–80 % frequency occurrence of low contamination levels) is in agreement with results found previously (Scott *et al.* 1982), indicating the relative efficiency of flushing as a means of controlling infection hazards associated with the domestic toilet.

Multiple application test

A multiple application test was used to investigate regular daily application as opposed to single usage of disinfectants. The hypochlorite was used for this test and was applied to seven kitchen sites in five houses. On each day contamination levels were determined immediately before disinfection and then 1–6 h later and the combined results tested for significance using the Wilcoxon Rank test.

Based on earlier tests which indicated a consistent response for all sites, combined values only are given for this test. Determination of the frequency of occurrence of disinfected sites (Fig. 2) indicates that the hypochlorite produced rapid and effective disinfection up to 1 h after application which was greater than that observed at 15 min in the single application test. On all 3 days some 82–94 % were disinfected and only 3 % of sites remained heavily contaminated.

Overall there was little evidence of a more sustained effect associated with repeated rather than single application of disinfectant. Although day 1 indicated

Table 2. *The effect of single or daily application of disinfectants or of detergent and hot water cleaning on the frequency of occurrence of enterobacteria species at environmental sites in the domestic kitchen, bathroom and toilet*

				Frequency of occurrence of enterobacteria spp.			
					Time after treatment (min)		
	Product	Day	Total No. of sites sampled	before treatment	15	90	180
Single application test	Detergent and hot water	1	92	60	52	56	50
	Hypochlorite	1	90	50	8	26	27
	Phenolic	1	92	43	33	25	29
					Time of treatment (h)		
					1	6	
Multiple application test	Hypochlorite	1	34	26	2	9	
		2	34	29	3	21	
		3	34	19	5	16	

some reduction in contamination levels at 6 h compared with pretreatment ($P = 0{\cdot}02$), no significant difference between pretreatment and 6 h was observed on either day 2 or day 3.

When day 2 and day 3 were compared with day 1, there was no evidence of any cumulative effect from repeated use of disinfectant; contamination levels before and at 6 h after disinfection on day 2 and 3 were not significantly lower than on day 1 and contamination at 6 h on day 2 was actually higher.

Identification of bacterial species

Although contamination levels give a measure of the efficiency of disinfection procedures, of equal importance is the elimination of potential pathogens particularly from sites where reservoirs of free-living organisms could become established. Identification of individual contaminants indicated that the range of bacterial species was similar to that found in the previous investigation (Scott *et al.* 1982). Species of enterobacteria included mainly *Escherichia coli*, *Enterobacter cloacae*, *Citrobacter freundii* and *Enterobacter agglomerans*. *Klebsiella* spp. (including *Klebsiella pneumoniae*) and *Proteus morganii* were also found. Although many of these species are not particularly harmful with respect to the normal healthy adult in the community, their isolation and identification can be used to evaluate the efficiency of disinfection and cleaning procedures in eliminating Gram-negative pathogens from a particular site.

Analysis of total isolation rates for species of enterobacteria in the various tests (Table 2) indicates that detergent and hot water had no effect on the overall occurrence of these organisms during the 3 h test period. By contrast, hypochlorite produced a significant reduction both at 15 min and at 1 h in the multiple application test. However, as might be expected from earlier assessments of

contamination levels, it was found that the maximum benefits achieved by hypochlorite disinfection were relatively short-lived. Within the total test period (3 or 6 h) a large proportion of sites were again found to be contaminated by the same, or in some cases, a different species of enterobacteria. Although the phenolic produced some reduction in isolation rates for enterobacteria, this was considerably less than that observed with hypochlorite, although there was some indication of a more sustained effect in that the isolation rate at 90 min was less than at 15 min.

DISCUSSION

In developing a satisfactory test protocol for cleaning and disinfection procedures in the home the major problem was to achieve standardization of test conditions whilst retaining the 'in use' nature of the test. Initial results from the single application test confirmed that the test design was adequate to demonstrate significant differences between disinfected and non-disinfected sites and between disinfectant and detergent-treated sites and it was decided that marginal effects demonstrated by increased standardization and test replication would be of little relevance in terms of demonstrating possible benefits in the home.

Although it has been stated that soap and water is an effective method of disinfection, the opinion of various workers is divided; Werner (1975) and Ayliffe, Collins & Lowbury (1966) found that detergent or soap and water was generally less effective compared with other disinfectants, whereas Duppre (1975) showed that soap and water were equally effective as disinfectants in reducing bacterial contamination of floors. Our results (Fig. 1 and Table 1) show no overall reduction in contamination levels by use of detergent and hot water alone and that initially there may be an apparent increase in contamination, possibly due to surfactant or mechanical break-up and redistribution of cell aggregates. Thus, although it is accepted that soap and water cleaning will physically remove contaminated material (food particles, grease, etc), the assumption that decontamination of surfaces can be achieved by detergent cleaning is not upheld by these results. Further work is required to determine how and to what extent hot water and other types of detergents might be used to achieve effective decontamination of environmental sites.

In contrast, both single and multiple application tests indicate that phenolic and hypochlorite disinfectants, as used in this investigation, produce a rapid and significant reduction in contamination levels and in the incidence of enterobacteria species at all types of wet and dry sites, including cloths as well as hard surfaces. It was found, however, that, for all sites, the maximum benefits obtained from disinfection were relatively short-lived. The rapid reappearance of contamination is probably mainly associated with re-usage of sites such as toilets and food preparation surfaces, but there are indications that, at wet sites such as sinks and also damp cloths, recontamination is due to local multiplication of residual contaminants not destroyed by the disinfection process.

To state that hypochlorite disinfectants are generally more effective than phenolics on the basis of this investigation would be inappropriate. The availability of domestic phenol disinfectants with Rideal Walker coefficients of greater than 4·6 suggests that higher in-use activity may be achievable by this type of

disinfectant. It should also be noted that commercially available bleach products vary considerably in strength (*Which Report*, 1976). Estimates from directions given on the pack suggest that, in use, concentrations can range from 100 to 1200 ppm, compared with a strength of 600 ppm as used in this investigation.

Although tests of this type provide a means of assessing and comparing domestic disinfection and cleaning methods under in-use conditions the authors recognize that, ultimately, potential health benefits derived from these procedures depend on the extent to which environmental contamination in the home actually represents an infection hazard. Relatively little information is available on this subject; published data implicating environmental contamination as a direct source of infection is mainly circumstantial (Datta & Pridie, 1960; Steere *et al.* 1975; Palmer *et al.* 1981). Compared to the hospital situation, the normal healthy adult is fairly resistant to infection, although certain individuals such as neonates or persons with reduced resistance due to disease or drug therapy must constitute an increased risk. A recent survey by Meers *et al.* (1981) found that 19·1 % of 18163 patients in hospital had infections, and that about half of these infections were acquired before entry into hospital. The main causative organisms identified in this survey corresponded with those most frequently isolated in the home (Scott *et al.* 1982) but it is difficult to assess how many, if any, of these infections were acquired from the home environment.

Precisely what proportion of household outbreaks of gastroenteritis, etc., arise from kitchen and toilet cross-contamination as opposed to badly cooked or inadequately stored food is also a matter for conjecture, but there is ample evidence of survival and transfer of potentially harmful bacteria via environmental surfaces in the home to suggest that high standards of hygiene, including decontamination (by disinfection or an effective cleaning procedure) of critical sites (particularly those associated with food or toilet hygiene), are of importance. De Wit, Brockhuizen & Kampelmacher (1979) showed that, following domestic preparation of chickens contaminated with *E. coli*, these organisms could be isolated from direct contact sites such as the chopping board and also from towel, door and tap handles where hand transfer must have occurred. A study of 73 homes containing babies infected with salmonella indicated frequent occurrence of the offending serotype at environmental sites (Van Schothurst, Huisman & Van Os, 1978). Our own investigations of the home environment indicated common occurrence of entero-bacteria including occasional isolation of salmonella (Scott *et al.* 1982).

Although further investigation is required to determine routes by which bacteria are actually transferred around the home, some immediate suggestions for improvements in hygiene can be made. Our previous investigations of the home confirm that the kitchen is probably the most important area in relation to harbouring and transferring infection. Observations suggest that whereas kitchen surfaces are most thoroughly cleaned as part of the clearing-up routine after food preparation, decontamination of surfaces should rather be encouraged before and between separate food-preparation activities. Our studies indicate that wiping with detergent and hot water alone may be insufficient to prevent transfer of contamination via surfaces from one food to another and a more effective decontamination procedure is required. In practice, disinfectants as currently available are little used for food hygiene; hypochlorites are generally mistrusted

because of their association with toilets and drains, whilst phenolic disinfectants are unsuitable because of food tainting.

This study particularly emphasizes the potential hazard associated with dishcloths, cleaning cloths and other wet cleaning utensils; unless cloths are thoroughly dried after use (which is often not the case) an effective decontamination procedure before, rather than after use is required to ensure that cloths do not act as reservoirs and disseminators of contamination in the kitchen, bathroom and toilet. Alternatively the use of disposable cloths and paper towels is suggested.

For sinks, toilets and other sites in more continuous use, our results indicate that, because of the problem of rapid recontamination, daily, or even more frequent disinfection, achieves little other than aesthetic cleaning and elimination of smell, and that continuous release or substantive disinfectant formulations would be required for effective decontamination. It may be argued that, under normal circumstances, such measures are unnecessary and that efforts should be concentrated on preventing transfer, rather than elimination of bacteria from these sites, by good hand hygiene and decontamination of hand-contact surfaces such as the toilet seat and handle. For general dry areas such as floors and walls there would seem little or no justification for disinfectant use.

Overall, however, although it may be that disinfection and/or cleaning procedures could be used to greater benefit in the home, one of the basic problems which remains is that of educating the general public in better hygiene practices and the basic principles of microbiology on which they are based.

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